(11) (A) No.

(45) ISSUED

(52) CLASS
C.R. CL.

(19) (CA) CANADIAN PATENT

(54) COMPUTER CONTROL OF ALUMINUM PRODUCTION

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Abstract of the Disclosure

Programmed digital computer control of the of aluminum by electrolysis is described. Charging o to individual reduction pots and changes in electrode are scheduled in accordance with monitored cell-resis current efficiency data, so that sick pots and anode averted, and more efficient operation of the reductic is obtained.

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The embodiments of the invention in which . exclusive property or privilege is claimed are defin follows:

1. A method for controlling the productio aluminum metal by the electrolysis of alumina fluxed cryolite and contained in a pot line, said pot line ing a plurality of pots with each such pot having an cathode electrodes connected in series with a source current, said method being characterized by the step

providing a plurality of adjustment positi said anode electrode relative to the cathode electro each of said pots,

determining the current efficiency for eac in said line in relation to each said position of sa electrode,

determining a maximized value of said curr efficiency for each pot, and

positioning said anode electrode of each p accordance with said maximized current efficiency fo pot.

2. A method as defined in claim 1, furthe characterized by the steps of

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with the equation

$$\%CE = \%CO_2 + \frac{\%CO}{2}.$$

4. The method of claim 1, including the s sampling the gases emitted from the anode electrode pot to determine the water vapor content of said gas said current efficiency of each said pot being deter accordance with the equation

$$\% \ CE = \%CO_2 + X \ \%H_2O + 1/2 \ [\%CO - Y \ \%H_2O]$$

where $\%CO_2$ is the volume percentage of carbon dioxi is the volume percentage of water vapor and %CO is t volume percentage of carbon monoxide present in sai being sampled, and X and Y are predetermined constar

5. A process for controlling the producti aluminum metal by electrolysis in a plurality of pot pot containing a bath comprising alumina fused in c and having an anode electrode and a cathode electro the electrodes of said pots being connected in seri one another and across a power source, said process prising the steps of

providing a plurality of positions for th electrode relative to the cathode electrode of each pots,

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$$\%CE = (\%CO_2 + \frac{\%CO}{2})\ A \exp(-\frac{B}{T})$$, where A an

predetermined constants and the base of the exponent function is the natural logarithm base e, and

controlling the anode electrode position f pot in accordance with said determined current effic for that pot.

6. The method of claim 1, including the s

determining the integral of said current e with respect to time for each pot in said line for p an indication of the production of aluminum within s

and controlling the position of said anode electrode for each pot in accordance with said integ current efficiency.

7. The method of claim 1, including the s

determining the differential of said curre efficiency with respect to time for each pot in saic for indicating when the anode effect condition will relative to said pot, and

controlling the recharging of each pot wi relative to the determined differential of said cur efficiency for said pot.

8. A method according to claim 1, wherei

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changes in said position,

means for determining the current efficien[illegible] said one pot of said aluminum metal production for ea[illegible] said anode position in accordance with a predetermin[illegible] relationship of the current utilization for producin[illegible] aluminum metal,

means for determining the change in said c[illegible] efficiency in relation to each predetermined change i[illegible] the position of the anode electrode in said one pot,

and means for controlling said anode elect[illegible] position for said one pot in accordance with the res[illegible] changes in said current efficiency.

10. Apparatus for controlling aluminum pr[illegible] as set forth in claim 9,

with said means for controlling said anode electrode position being operative to maximize said [illegible] efficiency in accordance with said respective change[illegible]

Background of the Invention

A This invention relates to an improved control apparatus for controlling the reduction electrolysis in a molten salt bath.

It is the prior art practice to reduce electrolysis of alumina fluxed in cryolite, usin individual furnaces or pots connected in series, ing one or more carbon electrodes.

A typical aluminum reduction pot or fu essentially of a movable carbon anode, a cathode trolyte of molten cryolite in which alumina is d overall reaction occurring in the furnace consis duction of alumina to aluminum, which is then de cathode, and the oxidation of carbon to carbon m carbon dioxide at the anode. The pot, in genera of a steel box lined with blocks of carbon, and bath of molten cryolite, with carbon blocks posi bottom and covered with molten aluminum to form Carbon anodes are movably suspended from above a the molten cryolite. An electrical power supply between the anode and cathode, such that a resul flows between the anode and the cathode to reduc to aluminum. The resulting molten bath, due to

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of the operation, becomes covered by a crust of frozer lyte and alumina. It is periodically necessary for ar to break away part of this crust and stir this broken rial into the bath, while fresh alumina is added above into a new crust. The electric current decomposes the in solution in the cryolite such that aluminum is depc the pool of molten metal already on the bottom of the In the course of the process oxygen is liberated at th of the anode where it reacts to form carbon dioxide wh off. The temperature of the operation is about 950°C. proportion of the aluminum reacts with the electrolyte a metal fog, which is carried to the anode by the circ of the electrolyte and is there oxidized to reduce son carbon dioxide to carbon monoxide.

According to Faraday's law, 1000 amperes of should produce in a typical reduction pot about 18 lbs aluminum per day; the usual practice provides only abc of metal being reduced, such that the efficiency of th in the process is about 85% and the anode gases conta 30% carbon monoxide. The theoretical decomposition vc alumina to yield aluminum and carbon dioxide is 1.7 vc to the resistance of the electrolyte, the leads and th circuit connections, the furnace operates in practice

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and stirred into the bath such that it becomes dissolv make the electrolyte more conductive and the voltage a furnace can then return to its normal value. Fresh al added over the broken area to form a new crust. The 1 operation is required about every 8 hours, but the int varies according to the design and method of operation furnace. Aluminum metal accumulates in a typical 40 k furnace at the rate of about 600 lbs. per day; at suit tervals, daily or perhaps every other day, a tapping v brought to the front of the furnace and molten aluminu is drawn out of the furnace.

One kind of operating condition that can occ needs correction is the so-called sick pot; this occur the alumina content of the molten salt bath becomes to either as a result of initially charging with too much or the accidental addition of too much alumina during of an electrolysis operation. During a sick pot condi bath temperature drops abnormally and both the cell-re and the current efficiency become too low. It is help restoring a sick pot to normal operation, to raise the and separate the electrodes of the pot in order to res cell resistance to a value near a predetermined and de

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the pot with a proper quantity of additional alumina.

In the aluminum industry, it has been commoı vide the input power supply line with an ammeter, so ı current passing through the series connected pots cou tected, and to provide each pot with a voltmeter conne across its electrodes, so that the voltage drop acros: and thereby the resistance in each pot or furnace cou termined. It has been known to adjust the position oı trodes of an individual pot, in order that the efficie the current in that pot might thereby be improved, anc been known for electrodes to be used that have embedde an iron or steel pipe, by means of which the anode gas sampled for analysis. The usual practice is to positi anode of each pot, in accordance with prior experience yield satisfactory cell-resistance values for the part pot involved. Moreover, although there has been propc frequent and even substantially continuous addition oı quantities of alumina to a pot, with the objective of ing the alumina concentration in the pot more constant in relatively narrow limits and thereby maintain the c efficiency at or near an optimal level, it has been mu common to control the process by making relatively lar

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$$\%CE \text{ (current efficiency)} = \%CO_2 + \frac{\%CO}{2}$$

as disclosed by Pearson et al and various modification including the modification of Kostyukov in accordance which the anode gas is also analyzed for water content order that a correction may be made for the water-gas-chemical reaction; the anode electrodes sometimes cont ders composed of hydrocarbons, and hydrogen from the h bons react with carbon dioxide to yield carbon monoxid water vapor. The McMinn paper further reports the wor Popov et al, in which by the use of the Pearson equati electronic computing equipment, percentage current-eff values were calculated and used in process studies.

Brief Summary of the Present Invention

An improved operation for the production of by the electrolysis of alumina fluxed with cryolite an tained in a plurality of series-connected pots is disc Each pot is provided with a movable anode having a pip therein, so that the anode gas generated along the bot face of the anode may be sampled and analyzed. Progra gital computer means is provided to monitor the bath t and the bath resistance in each pot and to calculate, basis of the anode-gas analysis, the instantaneous eff

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The prior art contains no appreciation of tl lar desirability of using the improved techniques in] aluminum production in accordance with the present in' nor of the magnitude of the benefits that are to be ol in an electrolytic aluminum production operation by re the simultaneous practice of (1) automatic electrode ; control to maximize current efficiency and (2) automat regulation to achieve improved power factor.

Brief Description of the Drawings

A more complete understanding of the present may be had from the foregoing and following descriptic taken together with the appended drawings, in which:

Figure 1 is an illustrative showing of a ty; aluminum reduction furnace or pot;

Fig. 2 is a schematic diagram of a control s use in practicing the present invention;

Fig. 3 is a graph showing an improvement in efficiency obtainable in accordance with the teachings present invention;

Fig. 4 is a curve showing the operational re ships of pot resistance, metal height, alumina concent and efficiency of the current for an illustrative cycl operation; and

trolysis.

In the electrolytic production of aluminum, sc the current converts alumina to aluminum and some of the is used to convert the anode carbon to carbon dioxide. reaction takes place where the aluminum so reduced is cc back to alumina and carbon monoxide. The total current fore is not used only to reduce aluminum but also for th other reactions. The resulting current efficiency is th of the useful current utilized for reducing alumina to a in relation to the total current passed to the process.

The alumina charged into the electrolyte prese the pot and the carbon in the electrode, which refers to anode electrode that can be made up of carbon containing briquettes, which due to the temperature of the process fused together into a substantially solid mass, react to aluminum and carbon dioxide by the reaction $2Al_2O_3+3C \rightarrow 4$ A secondary reaction occurs between the reduced aluminum the carbon dioxide to convert back to alumina and carbon ide by the reaction $2Al+3CO_2 \rightarrow Al_2O_3+3CO$. There is a th action between carbon dioxide and hydrogen to produce wa and carbon monoxide by the reaction $H_2+CO_2 \rightarrow CO+H_2O$. A dictable reaction rate occurs at the measured gas temper compared to a predetermined reference temperature, such by measuring the gas temperature the reaction rate can b

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analysis determined percentages of carbon dioxide CO_2 monoxide CO, compensated for temperature conditions, i lows:

$$\%CE = \left(\%CO_2 + \frac{\%CO}{2}\right) \quad A \exp(-\frac{B}{T}) \quad \text{to the bas}$$

When the current efficiency has been determi height or position of the movable anode electrode rela the stationary cathode electrode, as shown in the exam the Figure 1 furnace, can be adjusted to realize the h rent efficiency through a trial and error operation. tance of the pot drops off in the course of the normal tion operation, as shown by the curve of Fig. 4, and t sequently peaks to indicate when it is time to recharg pot with alumina to bring the current efficiency back the desired level. When a current efficiency peak, as in Fig. 4, is established by adjusting the anode elect position back and forth a predetermined small amount r to the peak condition, and before a rise in the pot re is excessive, a controlled searching for and resulting imization of the current efficiency can be realized. itoring the resistance of the pot periodically, a prec ahead of time can be made when it is desired to rechar pot with alumina to avoid the occurrence of the undesi anode effect as indicated by a rise in pot resistance. this way the computer can schedule the recharging of a

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and integrating the effective reduction of aluminum fc same pot to provide the sum of aluminum deposited witt pot to determine how much total aluminum has been redu the height of same relative to the anode.

When alumina is charged into a pot, it dissc the cryolite and forms the desired electrolyte for the lysis of alumina to aluminum. The position of the anc trode relative to the cathode electrode varies the cui efficiency; also, if the anode electrode becomes too c the aluminum level the current efficiency drops off. mum current efficiency is established by controlled ac of the electrodes by predetermined incremental amounts

C alumina concentration changes, this requires a change in the relati of the electrodes; the resistance of the bath also mus sidered as, when the alumina concentration goes down, becomes less conductive.

Some objectives of the present invention are mize the operational current efficiency, to inhibit th rence of anode effect by proper recharging of alumina desired time, to control and correct a sick pot condi occurs when an excessive charge of alumina is added by the electrode to increase the effective resistance of

Referring to Fig. 2, there is generally sho rality of aluminum pots 2, each having an exterior me and being interiorly lined with a suitable refractory like. The pots 2 each contain a bath 4 of fused-salt lyte, such as alumina fluxed with cryolite, and a bot 6 of aluminum produced by the electrolysis operation, inafter explained. Associated with each of the pots : pair of electrodes 8, 10, in general illustrative forr what modified from the showing of Figure 1, these bei ted in series with a direct current power source 12 tl conductor lines 14, 16, 18 and 20. In the line 14, tl provided an ammeter 22. Across each pair of electrode there is provided a voltmeter 24, 26, 28. The series current in each of the pots 2 is the same; and the vol dicated on each of the voltmeters 24, 26, and 28 indic resistance of the bath in its associated pot. This is course, dependent upon the relative positions of the e 8, 10 and the content of alumina in the bath 4, in eac The above-indicated equipment is conventional and well

In the practice of the present invention and erence to the showing of Figure 2, a movable electrode each of the pots 2 is provided with a hollow metal pip cated at 30, by means of which

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such connection line and thereby monitor the operation of respective pots. This provides information from which th ficiency of current utilization in each of the pots 2 may determined. As indicated at 42, this information is fed the digital computer 44.

If desired, the manner of calculating the curre efficiency of the basis of the anode gas analysis can tak account the water-vapor content of the anode gas. In oth words, the current efficiency can be calculated in accord with the formula:

$$\%C.E. = [\%CO_2] + \frac{44}{18}[\%H_2O] + \frac{1}{2}([\%CO] - \frac{28}{18}[\%H_2O]$$

where $[\%CO_2]$, $[\%H_2O]$, and $[\%CO]$ are the volume percentage the various anode surface gases indicated that are found in the respective gas samples from each pipe 30. A compe factor as a function of the reaction temperature can be i in the determination of circuit efficiency, with the reac rate a function of the temperature, to correct for the kn reducing reaction:

$$CO_2 + C \xrightarrow[\text{(temp)}]{} 2CO$$

to give a system control equation as follows:

$$\%C.E._{control} = \left(\%C.E._{measured}\right) A \exp(-\frac{B}{T})$$ to the ba

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periodically, for example, as scheduled by the compute immediately after aluminum metal has been withdrawn fr the pots 2, to check the level of molten aluminum meta ing therein, inasmuch as with the use of such an inter operating metal-level-sensing device, the problems ass with providing a level-sensing device that remains ope for long periods of immersion in the high-temperature ment of the fused salt electrolysis bath are reduced c encountered. As will be explained below, determinatic metal level in the pots 2 between such actual measurem be done accurately by operation of the computer 44. M within the detector device 54, or if desired, separate can be provided means for sensing the bath temperature

The computer 44 is supplied with stored powe limit information, as indicated at 58, such that in th tion of the provided control system, effective use may of the available electrical power without exceeding th termined demand limit, or with excursions of total pow beyond the demand limit being of controlled severity a tion and thus effectively minimized, to the end that a control and a maximum of benefit be obtained relative electrical power costs incurred in the operation of th

The computer 44 is operatively connected ...

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trode position.

As indicated by signal line 66, computer 44 nected to a suitable print-out or display device 68, dicates a desired alumina feed schedule and a suitable withdrawal schedule to guide the activities of a human again with the aim that the efficiency of the system t mized.

The mode of the operation of the programmed computer 44 will now be explained in greater detail. be understood, of course, that the exact manner of imp the computer control of the aluminum-production proces vary in accordance with the hardware already available selected for the implementation of the various functic tioned above, but it will be clear to those skilled in how, with suitable hardware, to practice the advantage trol hereinafter described.

In essence, the computer 44 sequences the op of the gas analyzing device 34 through connection 35 a ceives a periodic gas-analysis signal for each respect as indicated by signal line 42, and computing from th mation for each pot a current-efficiency signal is de through operation of above equation 2 or equation 3; signal is then, in turn, both integrated with respect

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a knowledge of the present calculated production of a metal and the predicted integral of the current effic

By comparison of calculated present metal l comparing the calculated projected metal level with a mined scheduled or reference level that is supplied t puter 44 as a part of its stored instruction program, or schedule for removal of molten metal from a given be determined. Though the metal removal may be done ways, one well known practice is to remove molten alu with the use of a vacuum snorkel arrangement. A comp the known electrode position for a given pot 2, and t lated level of molten metal therein, will reveal a ne moving the electrode or electrodes upward to remain o tact with or at a desired distance from the molten me in some instances it may be desirable to include in t for the computer 44 suitable analysis for and correct condition; in most instances, however, this particula culty will be otherwise automatically avoided by the practice of maximizing current efficiency through aut changing of electrode position, or by the means provi cure of a sick pot, wherein the position of the anode in response to a drop in pot resistance and in curren ciency.

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from a knowledge of differences in the time values st(the computer memory, to predict the time, after chargi the onset of anode effect may be expected and accordir need to charge the pot with alumina. On the basis of diction, the computer 44 operates the print-out device indicate to an operator in an out-printed schedule of for the next ensuing period of operation, e.g., a peri about 4 hours, the need for charging the pot involved alumina at about the time that the onset of anode effe expected to occur for preventing the latter effect. C attention must be paid to the amount of molten metal i so that it does not become overful; it may be desirabl event to withdraw periodically molten metal and then a alumina shortly thereafter.

The exact manner of programming the computer ject to some variation, depending upon the importance attached to the various operations in the process. Th four main considerations here, and they may be ranked ly in different installations, depending upon the prac circumstances involved. If, for example, adequate ove limit power is available and is not especially costly, be important, in the order named, to (1) cure sick pot

stantially less important effect on the overall produc of the totality of pots than does, for example, a rati sick pot in five.

Having established priorities among the vari siderations mentioned above, persons of ordinary skill art may then develop a suitable control program for th within the scope of the present invention, giving rega following further teachings.

When a pot is sick, the bath temperature and ance as determined from current and the voltage betwee trodes, tend to become low, as does the current effici Monitoring for sick pots involves checking these facto predetermined standards stored in the computer memory, desired order, with a corrective sub-routine as previc forth being initiated whenever the results of the moni operation indicates a need for corrective action. The tive sub-routine involves raising the anode electrode crease the resistance, as indicated by the observed vc between the electrodes to a desired value, or to maxin current efficiency in the given pot in question as det by anode-gas analysis. Curing or preventing the anode requires the charging of additional alumina to the pot tion. It is a matter of choice whether charging of al

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cost of producing primary aluminum, and control measu: may importantly influence the power cost are thus of able importance to the resulting economics of the pro not infrequently happens that a primary aluminum plan largest single customer of its local power company, t where its need for power influences the local power c choice of capacity for power generation equipment. L users of electric power are familiar with rate schedu set a selected demand limit, e.g., for example 200,00 provide for additional charges if it is exceeded. Su schedules also are based upon the premise that a cert factor, such as 70%, a percentage of the total availa over a period will be used by the customer, and provi additional payments in the event that usage of power above such level. Another consideration is that, so the individual pots of a total line are each operatin ciently, it is best to use as much power as can be ha passing the demand limit, for in that way production can be maximized and costs per unit of production can mized.

The nature of the improvement in accordance present invention in observance of power demand limit

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As indicated above, the importance that is t upon the matter of keeping the power used by the pot l limits will influence the stored control program that used in the computer. Whatever program is used, it is upon periodically monitoring the voltage values from t 24, 26, 28 shown in Figure 1 to arrive at a total vol for the line and then multiply this by the line curre by the ammeter 22. This gives the instantaneous KVA the system. The same value can be obtained, without t tions, by using a voltmeter across the lines 14 and 2 tain the total voltage value. If KVA is integrated o one obtains a KVAH or power consumption figure. It i of choice whether instances of exceeding the power-de are to be avoided altogether, or such instances are t trolled to, say, 10% over, and it is a matter of choi the program used shall be one that causes corrective some sort to be taken as soon as the load factor for lar period of time falls below 95%, or one that does any corrective action to be taken until the load fact to some predetermined level such as down to 85%. Wha sential, in accordance with the present invention, is there be provided the control means in conjunction wi aluminum pot line, for computing rapidly the load fac

shown in Figure 1 and/or alumina can be added, this be either by automatic means or manually on the basis of tions that can be made to appear, in accordance with a program for the computer 44, on the print-out device 6 ably, electrode position control is used, as this furr particularly fast-acting means of correction, but for rection of longer-term departures from the optimal or erable conditions defined by the stored program in use suitable but slower-acting corrective measures will fi

As shown in Figure 2 a gas analysis apparatu operative with a pipe 110 extending down through the a electrode 100 to sense the gas forming at the face of trode for analysis in relation to percentage of carbor and percentage of carbon monoxide. The anode 100 can be made up of the well known carbon and sand mixture i form of briquettes which, at the temperature of the pr becomes a solid mass where it comes in contact with th 106. The computer can follow a predicted mode of oper wherein the control anticipates the current for each p schedules the operation for recharging each pot by mea the resistance across the pot in relation to voltage a rent. In this way the pot is run at maximum throughpu

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electrolyte and cathode electrode is proper. Irrespe the accuracy of the measurement here provided, and th lation of current efficiency CE by the above equation paring the change in current efficiency as calculated ferent positions of the anode, the anode position for current efficiency will be found through the on-line tation here provided and in accordance with the illus of Figure 5. In this way, periodically, a hunting or and error operation is undertaken relative to adjustm the position of the anode electrode in relation to th lyte and the stationary cathode electrode.

If desired a feed conveyor for the alumina provided in conjunction with the plurality of aluminu pots to feed alumina to each pot in accordance with a schedule contained in the memory of the computer. Th can monitor the quality of cryolite within each pot, changes very slowly, so a sample taken once a day wou be adequate. By adding to the bath a few pounds of a every predetermined period, such as a fraction of an concentration of alumina within the electrolyte shoul substantially constant and within controlled concentr The feed rate of alumina to an individual reduction p

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In accordance with the present invention the resistance is monitored to predict changes in the al centration and determine when alumina charges should In addition, the use of off gas from the anode elect face is utilized to maintain current efficiency at t level by adjusting the anode cathode distance to eff increase overall energy efficiency.

It is clear that the suggestive method of mea the analysis of gas leaving a pipe which is embedded anode electrode will give a sample of the gas as act formed at the face of the electrode. The sample sho become contaminated with ambient air. The compositi gas should truly reflect the reactions occurring at the electrode and not require correction for ingress nitrogen.

The computer calculates the current efficien upon gas analysis in accordance with the above equat as follows:

$$\%CE = \%CO_2 + \frac{\%CO}{2}$$

This suggests that the content of carbon dioxide, car monoxide and, if the third reaction relative to hydr included as represented by above equation (3), the m content of the gases coming off the face of the elec should be measured. Furthermore since these equatio terms of weight, the percentage volumes as measured

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Similarly electrode reduction rate is also proportior same product, therefore:

$$\sum_{o}^{t} Al = K_1 \sum_{o}^{t} I(\%CE)$$

The theoretical potential for the electroly duction of alumina is about two volts. If current ef is used to control electrode position, the constraint the potential should not fall substantially below two i.e., the electrodes must not be so close to the meta that the resistance through and therefore potential a bath are less than that required for electrolysis, no resistance across the bath be so high that excess ene used in warming up the bath and probably increasing t tude of the above described second reaction.

Maximum current efficiency will lie somewhe these two constraints. It is also likely that the cu current efficiency plotted against electrode position a substantially flat peak as shown in Figure 4, so th band control of electrode position is suitable. Furtl the volume of aluminum produced in the given time T w greater than the volume of electrode consumed. Betwe the bath, therefore, one would expect the electrode t

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of time as shown by curve 206. The shape of the resi curve is not changed by a movement of the electrode b displaced. Anode effect is revealed by a sharp rise resistance across the pot towards the end of the cycl t2 and t3, and accompanied by a sudden fall in curren cy which indicates that the pot needs recharging with A sick pot (not shown in Figure 4) would be revealed duction in the resistance, accompanied by a falling o rent efficiency; this indicates the pot is overfull o and the electrodes should be raised either until the falls to a normal value or the current efficiency is present maximum obtainable.

Clearly the maximum current efficiency obta any time will vary with current, the amount of cryoli concentration of alumina in the bath and the bath tem When a new charge of alumina is first inserted some e be used in warming up the new material as well as in sis particularly if the anode effect has been suppres feeding new material at an earlier point in the cycle bath temperature has not risen excessively.

Some basic objectives of the present contro may be stated as follows:

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individual pots will be (a) current, (b) resistance, current and individual pot voltage, (c) current effi from gas analysis, and (d) bath temperature.

At regular intervals, for example once per reading will be taken on the liquid metal level and of the cryolite bath. The liquid metal level can be at once every time a pot is tapped. By experiments, lation can be made between maximum attainable current cy, the bath resistance, and the aluminum concentrat different current levels. Furthermore, the width of rent efficiency curve peak, as generally shown in Fig in terms of corresponding anode electrode travel will ed at the middle of the cycle, i.e., a predetermined alumina concentration, for various values of electro rent. All of the above data will be stored in the me the computer.

Assume that an individual pot is on manual and it is desired to place it under computer control. operator will adjust the electrode position in accor his own past successful experience and will now rech pot. The computer control system is then made opera assume control of the operation. The computer will

of the metal bath. Should this be accompanied by the of the current efficiency curve as shown in Figure 5 a desired value, the nominal position of the anode, w computer will be hunting about this nominal position, raised by a corresponding amount.

As the batch proceeds, the differential of times the percent efficiency current efficiency %CE c puted, and when this is equal to zero, it will indica beginning of anode effect. There is a fixed ratio $\frac{t2}{t3}$ reference to the illustration of Figure 4, which will time when recharging should take place to be predicte values of t1 and t2 will be noted at specified values differential $\frac{d}{dt}$ (I · %CE), since these have correspon alumina content values. Thus by noting t1 and t2 for sponding values of $\frac{d}{dt}$ (I · %CE), the time t3 may be d and the recharging of the pot scheduled accordingly. diction will be on the basis of production rate remai changed. Should the electrolyzing current change, th ing schedule will have to be brought forward or delay corresponding amount.

For the detection of sick pots, if an exces of alumina is charged at the beginning of the cycle, an excess of alumina fall into the pot at sometime wi

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electrodes of one pot are moved, the control of line at a substantially constant value is highly desirable also makes more accurate the prediction of recharging for scheduling. To make this prediction at an early the cycle, i.e., as soon as the pot has been restabil charging, the values of t_4 and t_5 at specified values can be noted, and t_3 predicted from the ratio:

$$\frac{t_5 - t_4}{t_3 - t_5} = K,$$ where K is a known relations

the past occurrence of the anode effect condition.

In general, the pot control program by the is as follows:

1. Initiated by operator after recharging alumina.

2. Examine bath temperature and check for

3. If pot is sick, raise electrodes until is adequate. Otherwise pass to (4).

4. If pot is normal and stabilized, optimi current efficiency.

5. Begin integration and differentiation o

6. If bath height rises excessively, deter

$\sum_{\wedge}^{t} I \ \%CE,$ raise anode electrode an amount proportio

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and include $\sum I\ \%CE$ and $\frac{d}{dt}$ (I%CE).

12. Print out each hour the present schedule three hours. This should take into account present al charging mechanism position and location of the pots r alumina in the lines. Predetermined tolerances (plus are allowable on the recharge time.

The primary purpose of the demand control is tain a high load factor and to control the KVA demand total KVAH over the demand period is to the greatest p extent neither above nor below the given level. At th ning of a demand period a reset pulse is received from power company metering. This indicates to the compute should initialize all programs and counters for the fo demand period. As the power is used by the plant, pul resenting units of KVAH are transmitted to the compute KVAH used is continually accumulated and compared with termined high and low KVAH usage rates. If the actua consumption exceeds either of these limits some actio taken to increase or decrease the KVA into the pot li is done by adjusting the taps on the line transformer predetermined limits, by means of contact closure out the computer. The contact closure output energizes th changer control which moves the tap to a new position

change or modification therein which may be made witho parting from its spirit and scope.

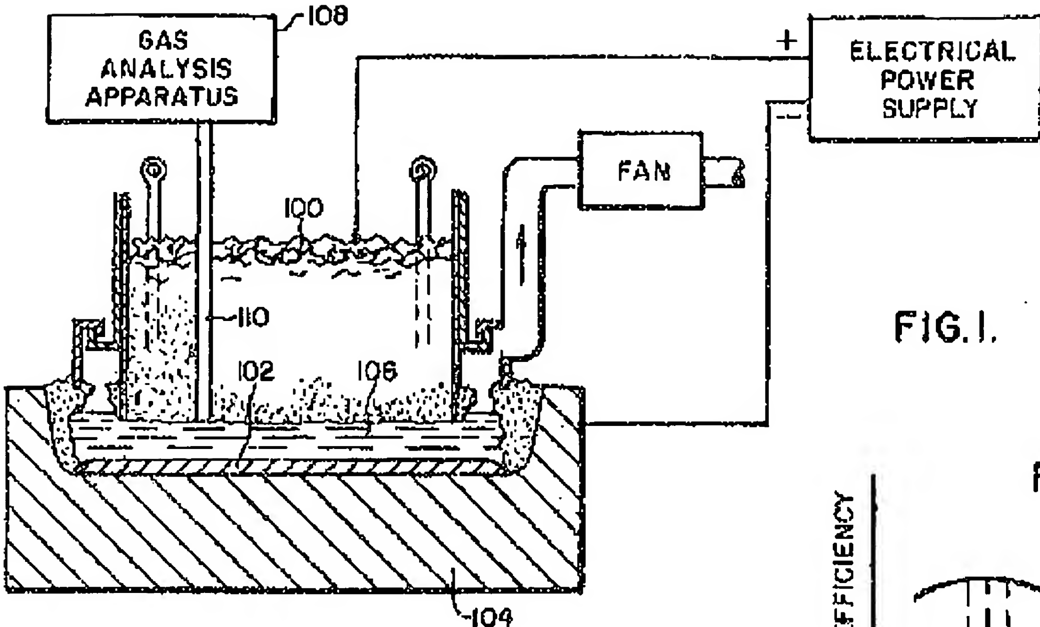


FIG. 1.

FIG. 5

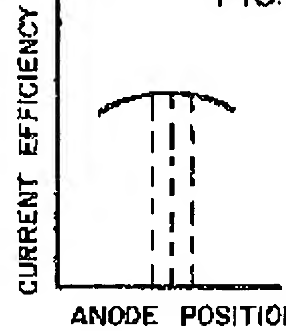


FIG. 4.

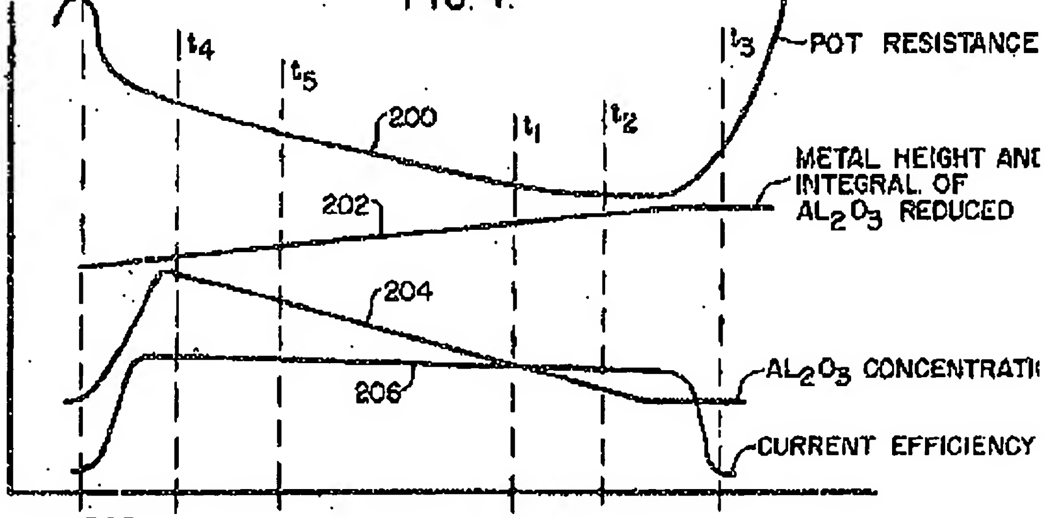
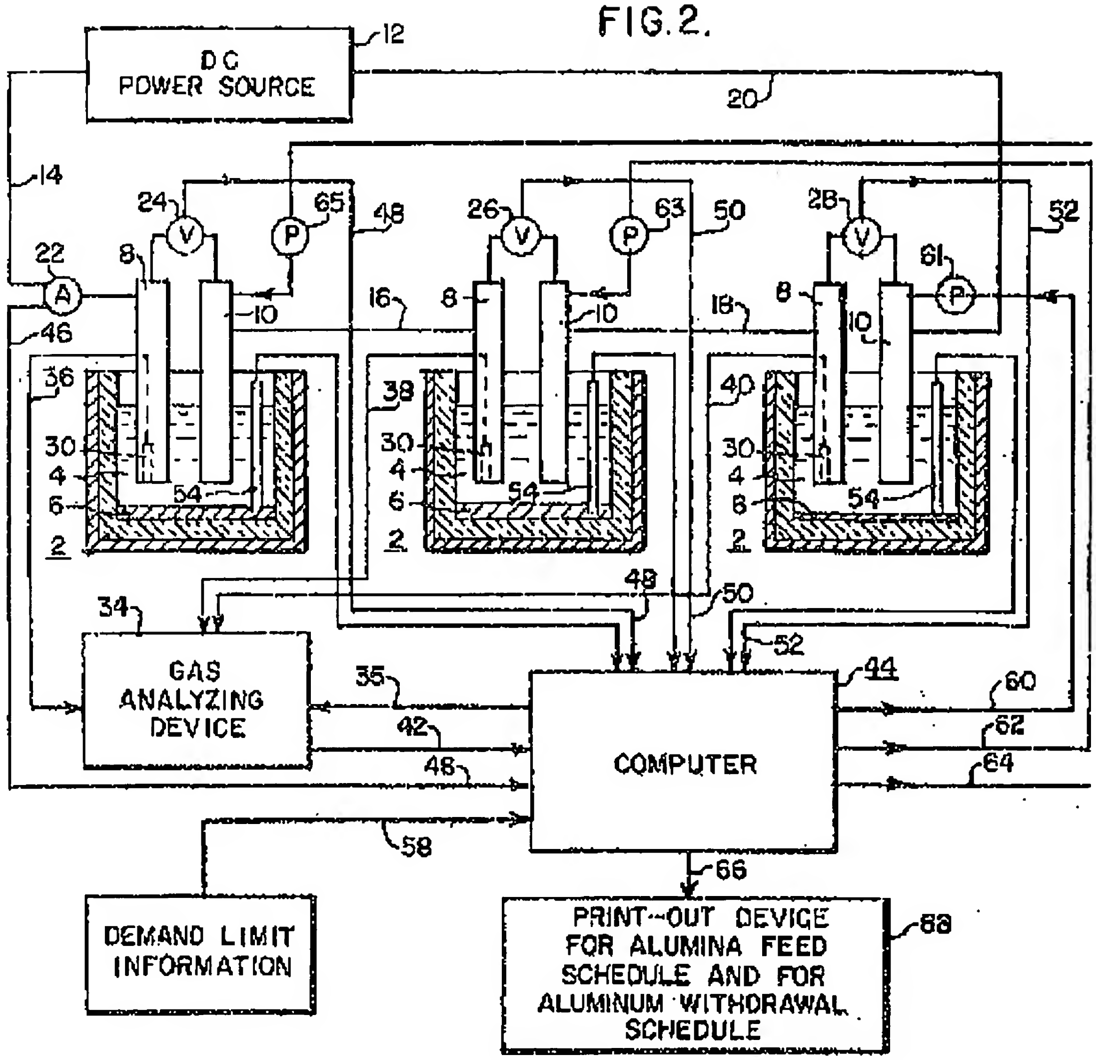


FIG. 2.


DC POWER SOURCE
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GAS ANALYZING DEVICE
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COMPUTER
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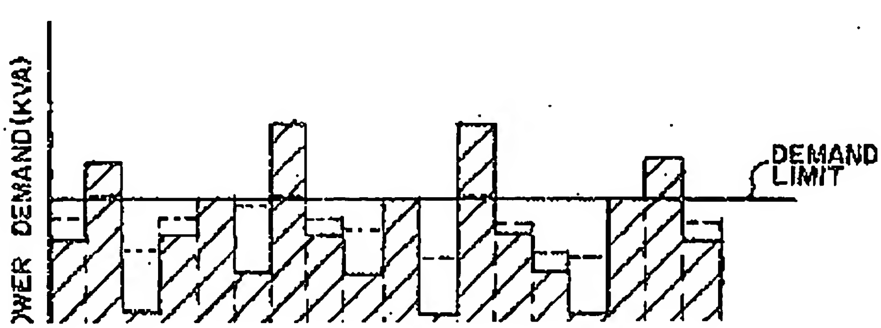
DEMAND LIMIT INFORMATION
PRINT-OUT DEVICE FOR ALUMINA FEED SCHEDULE AND FOR ALUMINUM WITHDRAWAL SCHEDULE
68


DEMAND LIMIT
OWER DEMAND (KVA)